MODELED ESTIMATES OF HUMAN HEALTH AND ECOLOGICAL IMPACTS FROM THE ESTABLISHMENT OF A NORTH AMERICAN EMISSIONS CONTROL AREA (ECA)

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Abstract

Previous studies have concluded that emissions from ocean-going marine vessels may cause as many as 60,000 deaths annually worldwide. In this study, emissions of NOx, SOx, and PM from the shipping sector are shown to contribute significantly to poor air quality across North America and are increasingly contributing to the amount of sulfur and nitrogen being deposited in the U.S. and Canada. The outputs from a series of regional air quality simulations, using U.S. EPA's Community Multiscale Air Quality (CMAQ) modeling system, were paired with several "downstream" models to look at the impacts of potential regulations affecting ocean-going vessels on human health and welfare. As part of this analysis, several innovative linkages were developed to relate projected changes in air quality to impacts on health and welfare metrics such as human mortality, acidification of aquatic and terrestrial ecosystems, and forest health. This poster briefly summarizes the results of this integrated modeling and demonstrates that reductions in ship emissions from the use lower sulfur fuels would produce widespread benefits that would outweigh the costs of the fuel switch. Additionally, several sensitivity tests were conducted to quantify the air quality and health impacts of ship emissions at various distances from the North American shoreline. Based on this modeling, a joint proposal from the United States, Canada, and France to amend MARPOL Annex VI to designate specific areas of North American coastal waters as an Emission Control Area (ECA) was accepted by the International Maritime Organization (IMO) in March 2010. This ECA is scheduled to begin to reduce emissions as early as July 2010 and is expected to deliver substantial public health benefits to many people living in the U.S., Canada and French territories, as well as to marine and terrestrial ecosystems over the next decade.

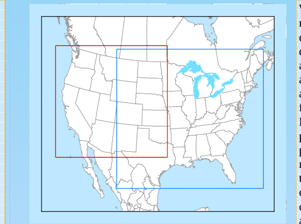
Background

A natural by-product of a global economy is the need for transportation of commodities from their source of origin to their source of consumption. Steady growth in international shipping over the past half-century has resulted in emissions from this sector increasingly being viewed as a significant contributor to degraded air quality and health worldwide. Recent studies have shown that shipping-related emissions are responsible for as many as 60,000 cases of premature mortality every year globally (Corbett et al., 2007; Winebrake et al., 2009).

However, emissions from international shipping and the associated air quality problems have traditionally been difficult to regulate due to jurisdictional issues (Shrader, 2008). To address this issue, the International Maritime Organization (IMO), an agency of the United Nations, established Annex VI of the MARPOL convention to assist in the prevention of air pollution from ships. This international convention allows countries to apply for a designation of an Emissions Control Area (ECA) for specific portions of their coastal waters. Ships operating in a designated ECA are required to reduce to not exceed 0.1 percent fuel sulfur by 2015. This requirement is expected to reduce PM and SOx emissions from this sector by more than 85 percent. Additionally, beginning in 2016, vessels operating in an ECA will need to meet engine emissions standards that will result in an 80 percent reduction over present-day NOx emissions. In March 2010, the International Maritime Organization (IMO) member states formally agreed to designate a large portions of U.S. and Canadian waters as an ECA. Based on modeling analyses described further in this poster, the decision was made to extend the North American ECA boundary to 200 nautical miles from the relevant shorelines. As shown in the rest of the poster, this regulatory action is expected to significantly improve air quality along the affected coastlines as well as improve ecosystem health in the same areas.

Gridded estimates of NOx emitted in 2020 from Category 3 marine vessels in tons per year (EPA, 2009). Note that preferred shipping routes tend to concentrate emissions from this sector along the California coast and several major U.S. ports (e.g., Houston and New Orleans).

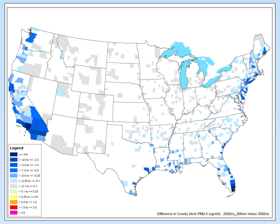
U.S. EPA Air Quality Modeling Configuration



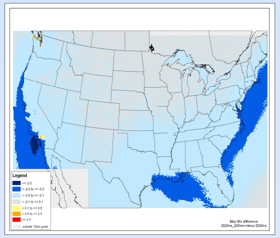
When considering the potential effects of any particular air quality regulation, it is common practice to apply a photochemical air quality modeling system to estimate the change in regional air quality expected to occur with the emissions reductions proposed as part of the control program. At their core, air quality models are quantitative approximations of the numerous complex physical and chemical interactions in the atmosphere that determine the formation and fate of air pollutants in the atmosphere. The U.S. EPA has traditionally used air quality modeling results to support policy decisions and as inputs into regulatory impact analyses. As part of this exercise, a fine-resolution, national air quality modeling analysis was performed to estimate the effect in 2020 of the proposed ECA emissions reductions on future 8-hour ozone concentrations, annual fine particulate matter (PM2.5) concentrations, visibility levels, and acid deposition to watersheds and ecosystems across the U.S.

EPA's Community Multi-scale Air Quality (CMAQ) modeling system was used in this analysis (Byun and Schere, 2006). CMAQ is a publicly available, peer reviewed, state-of-the-science model consisting of a number of science attributes that are critical for simulating the oxidant precursors and nonlinear organic and inorganic chemical relationships associated with the formation of ozone as well as sulfate, nitrate, and organic aerosols. The CMAQ modeling analyses were performed for three separate domains, as shown above. This modeling used a parent horizontal grid of 36 km (black boundary) with two nested, finer-scale 12 km grids covering the Eastern (blue) and Western U.S (red). The model extends vertically from the surface to 100 millibars using a sigma-pressure coordinate system. Air quality conditions at the outer boundary of the 36 km domain were downscaled from the global GEOS-Chem model and did not change over the simulated scenarios. Meteorological inputs from 2002 were used as determined by separate retrospective MM5 meteorological modeling.

Expected Impacts On Ozone & Fine Particulate Levels



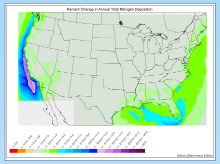
High levels of ozone and fine particulates are expected to continue to be a problem over the U.S. for at least the next two decades, despite recent extensive mitigation programs for land-based sources. Without any further action, emissions from ocean-going vessels would contribute a larger share to the projected levels of ozone and fine particulates in the future as emissions from other sources decrease. The CMAQ modeling projects that the designation of an ECA within 200 nautical miles for the U.S. coastline will result in large improvements in PM2.5 air quality. The figure (left) shows the improvement in peak 24-hour PM2.5 levels in 2020 as a result of the lower SOx and NOx emissions. The air quality benefit will be largest in coastal areas, exceeding 1.0 ug/m3 annually in some locations. This is a significant increment of the current U.S. annual PM2.5 air quality standard (15.0 ug/m3).

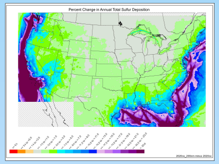


Large improvements in ozone air quality are also projected to occur as a result of an ECA designation. Some locations are projected to experience reductions of 0.5 to 2.0 ppb by 2020 as a result of the tighter ECA NOx engine standards. The figure (left) shows the change in average daily maximum 8-hour ozone levels in 2020 as a result of this reduction in shipping emissions. The modeling also shows some limited areas of ozone increases over portions of Los Angeles and Seattle due to less titration of ozone when NOx shipping emissions are reduced. However, as local emissions of U.S. NOx are further reduced in these areas in the future to meet national air quality standards, it is expected that the ozone chemistry will become increasingly favorable to NOx controls. Based on the modeled air quality improvements, the ECA designation is estimated to result in benefits ranging from **$27-60 billion dollars** annually due to reduced health costs and reduced premature mortality.

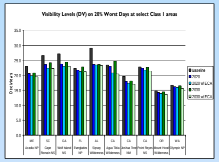
Impacts on Deposition, Visibility, & Ecosystems

Not surprisingly, given the large reductions in NOx and SOx emissions that will occur in the coastal regions over the next decade due to the ECA designation, the modeling also projects large reductions in total nitrogen and total sulfur deposition over the U.S. Reductions of more than ten percent in sulfur deposition are projected in most coastal areas by 2020. The figures below show the change in total nitrogen (lower left) and sulfur (lower right) deposition in 2020 based on the CMAQ modeling. These reductions in acid deposition lead to a corresponding improvement in ecosystem health, which was modeled separately. EPA conducted a case study looking at the Adirondack Mountains and the Blue Ridge Mountains. The ecosystem modeling showed that shipping emissions contributed to cases in which more acid deposition occurred than could be neutralized.





Lastly, among the numerous positive environmental outcomes of the ECA designation, the modeling showed that improvements in visibility can be expected in many scenic national parks over the U.S. (left). The ECA emissions reductions are projected to result in 2-5 percent improvements in visibility in numerous locations. In some western locations, the improvements from the ECA program are equal to the improvements resulting from all other sector control between 2002 and 2020.



Conclusions

The U.S. coastline and many parts of the interior of the country will experience significant improvements in air quality due to reduced fine particulates and ozone precursors in the future as a result from ships complying with ECA standards. Coastal areas will experience the largest improvements; however, significant improvements will extend hundreds of miles inland to reach nonattainment areas in states such as Nevada, Tennessee and Pennsylvania. National treasures such as the Grand Canyon National Park and the Great Smoky Mountains will also see air quality improvements. Additionally, the North American ECA is expected to yield significant health and welfare benefits. EPA estimates that the annual benefits in 2020 will include preventing between 5,500 and 14,000 premature deaths, 3,800 emergency room visits, and 4,900,000 cases of acute respiratory symptoms in 202. For those that are interested, considerably more detail on the ECA modeling methodology and results is contained within the technical support document that supported the ECA designation (U.S. EPA, 2009)

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